
**Mechanical vibration — Evaluation of
machine vibration by measurements on
non-rotating parts —**

Part 4:
Gas turbine driven sets excluding aircraft
derivatives

*Vibrations mécaniques — Évaluation des vibrations des machines par
mesurages sur les parties non tournantes —*

*Partie 4: Ensembles de turbines à gaz, à l'exception des turbines dérivées
de celles utilisées en aéronautique*



Contents

	Page
1 Scope.....	1
2 Normative references	2
3 Measurement procedures.....	2
4 Evaluation	3
4.1 Criterion I: Vibration magnitude	3
4.2 Criterion II: Change in vibration magnitude	5
4.3 Operational limits	5
4.4 Supplementary procedures/criteria.....	6
4.5 Evaluation based on vibration vector information	6
Annex A (normative) Evaluation zone boundaries.....	7
Annex B (informative) Example of setting ALARM and TRIP values	8
Annex C (informative) Bibliography.....	9

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10816-4 was prepared by Technical Committee ISO/TC 108 *Mechanical vibration and shock*, Subcommittee SC 2 *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

- *Part 1: General guidelines*
- *Part 2: Large land-based steam turbine generator sets in excess of 50 MW*
- *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ*
- *Part 4: Gas turbine driven sets excluding aircraft derivatives*
- *Part 5: Machine sets in hydraulic power generating and pumping plants*
- *Part 6: Reciprocating machines with power ratings above 100 kW*

Annex A forms an integral part of this part of ISO 10816. Annexes B and C are for information only.

Introduction

ISO 10816-1 is the basic document which describes the general requirements for evaluating the vibration of various machine types when the vibration measurements are made on non-rotating parts. This part of ISO 10816 provides specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine driven sets. Measurements at these locations characterize reasonably well the state of vibration.

Two criteria are provided for assessing the machine vibration. One criterion considers the magnitude of the observed vibration; the second considers changes in the magnitude. It must be recognized, however, that these criteria do not form the only basis for judging the severity of vibration. For gas turbine sets, it is also common to judge the vibration based on measurements taken on the rotating shafts. Shaft vibration measurement requirements and criteria for gas turbine sets are addressed in separate documents, ISO 7919-1 and ISO 7919-4.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 4:

Gas turbine driven sets excluding aircraft derivatives

1 Scope

This part of ISO 10816 gives specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine driven sets.

The vibration criteria provided in this part of ISO 10816 apply to heavy-duty gas turbine sets. Aircraft derivative gas turbines (including gas turbines with dynamic properties similar to those of aircraft derivatives) are excluded from this part of ISO 10816. Large differences exist between these two turbine types in, for example, casing flexibility, bearing design, rotor to stator weight ratio and mounting structure. It is therefore necessary to establish separate criteria for these two turbine types.

This part of ISO 10816 is applicable only to heavy-duty gas turbines used in electrical and mechanical drive applications covering the power range above 3 MW and a speed range under load between 3 000 r/min and 20 000 r/min. This includes gas turbines directly coupled to other prime movers such as steam turbines, but the evaluation of the steam turbine vibration is not dealt with in this part of ISO 10816 (see the following exclusion list). It also includes any driven equipment not included in the exclusion list below.

The following are excluded from this part of ISO 10816:

- gas turbines with power outputs less than or equal 3 MW (see ISO 10816-3);
- gas turbine driven pumps (see ISO 10816-3);
- coupled steam turbines and generators with outputs less than or equal 50 MW (see ISO 10816-3);
- coupled steam turbines and generators with outputs greater than 50 MW (see ISO 10816-2);
- coupled compressors (see ISO 10816-3);
- gearbox vibration (see below).

The criteria of this part of ISO 10816 are applicable to the vibration measured on the bearing housings or pedestals of gas turbines and driven equipment using fluid-film bearings. They assume that the measurements are *in-situ* broad-band values taken under normal steady-state operating conditions. This part of ISO 10816 encompasses machines which may have gears or rolling element bearings but does not address the evaluation of the condition of those gears or bearings.

NOTE Gear vibration may be included in a future edition of this part of ISO 10816. Vibration of gears is presently addressed in ISO 8579-2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10816. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10816 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7919-4:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 4: Gas turbine sets*

ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines*

3 Measurement procedures

The measurement procedures and instrumentation shall comply with the general requirements of ISO 10816-1 and are as follows.

For gas turbines, the measurement system used shall be capable of measuring broad-band vibration over a frequency range from 10 Hz to at least six times the highest shaft rotational frequency. If, however, the instrumentation is also to be used for diagnostic purposes, a wider frequency range and/or a spectral analysis may be necessary. If measurements from different machines are to be compared, care shall be taken to ensure that the same frequency range has been used.

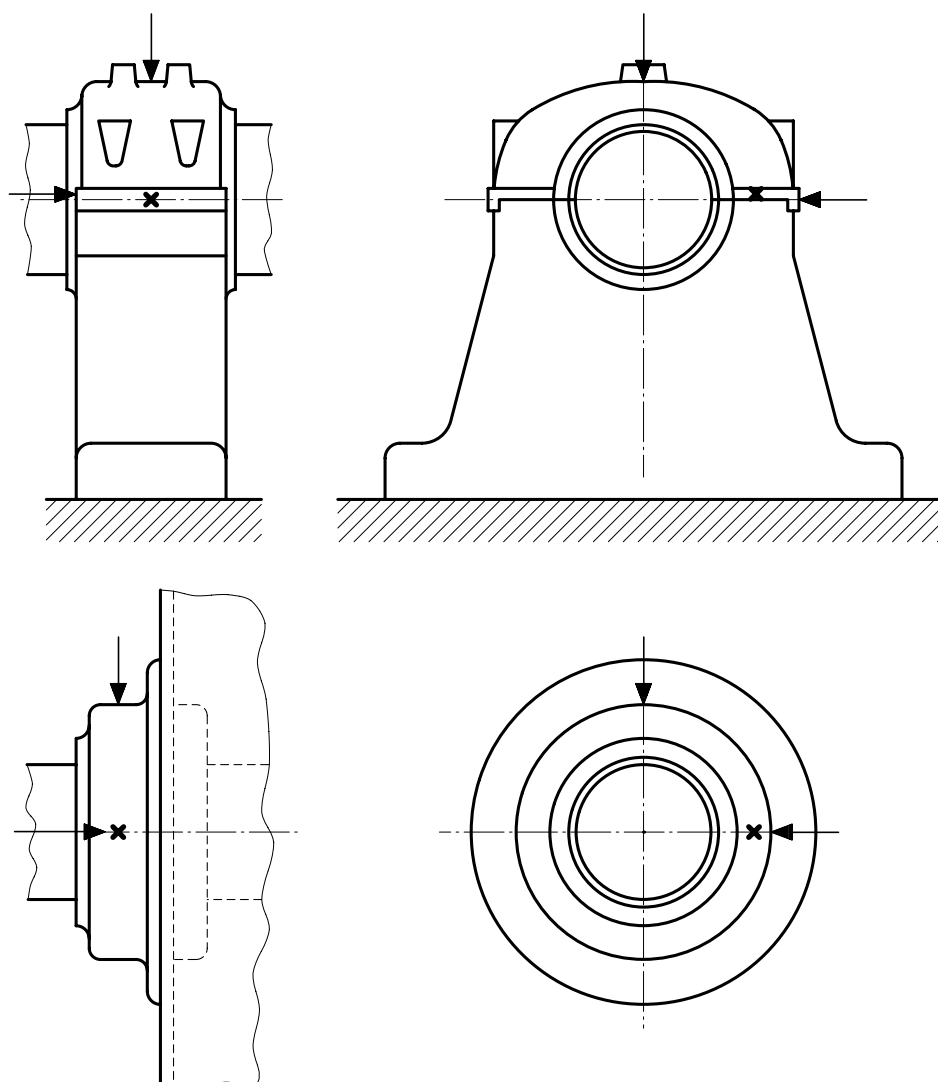
The locations of vibration measurements shall be such that they provide adequate sensitivity to the dynamic forces of the machine but are not unduly influenced by external sources (such as combustion vibration, gear mesh vibration, etc.). Typically, this will require measuring in two orthogonal radial directions on each bearing cap or pedestal, as shown in figure 1. Although the transducers may be placed at any angular location on the bearing housings or pedestals, vertical and horizontal directions are usually preferred.

A single transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information on the magnitude of the machine vibration. In general, however, caution should be observed in evaluating vibration from a single transducer at a measurement plane since it may not be oriented to provide a reasonable approximation of the maximum value at that plane.

The characteristics of the measuring system should be known with regard to the effects of the environment including:

- temperature variations
- magnetic fields
- sound fields
- power source variations
- transducer cable length
- transducer orientation.

Particular attention should be given to ensuring that the vibration-sensing transducers are correctly mounted and do not degrade the accuracy of the measurement.



NOTE The evaluation criteria in this part of ISO 10816 apply to radial vibration on all bearings and axial vibration on thrust bearings.

Figure 1 — Measurement points on main bearings

4 Evaluation

ISO 10816-1 provides a general description of the two evaluation criteria used to assess vibration severity on various classes of machines. One criterion considers the magnitude of observed broad-band vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

4.1 Criterion I: Vibration magnitude

This criterion is concerned with defining limits for absolute vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the environment through the support structure and foundation. The maximum vibration magnitude observed at each bearing or pedestal is assessed against four evaluation zones established from international experience. The maximum magnitude of vibration measured is defined as the vibration severity.

4.1.1 Evaluation zones

The following evaluation zones are defined to permit a qualitative assessment of the vibration of a given machine and to provide guidelines on possible actions.

Zone A: The vibration of newly commissioned machines would normally fall within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

Numerical values assigned to the zone boundaries are not intended to serve as acceptance specifications, which should be subject to agreement between the machine manufacturer and customer. However, these values provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. In certain cases, there may be specific features associated with a particular machine which would require different zone boundary values (higher or lower) to be used. In such cases, it is normally necessary for the manufacturer to explain the reasons for this and, in particular, to confirm that the machine will not be endangered by operating with higher vibration values.

4.1.2 Evaluation zone limits

Values for the zone boundaries are given in table A.1. The zone boundary vibration values were established from representative data provided by manufacturers and users. Since the data showed significant spread, the zone boundary values should be considered only as guidelines. The values in table A.1 apply to vibration measurements taken under steady-state operating conditions at rated speed or speeds. It should be noted, however, that the vibration of a gas turbine can be influenced by its mounting system and coupling arrangement to driven machines.

This part of ISO 10816 does not provide different evaluation zone values for gas turbine driven sets mounted on rigid and flexible foundations. This is consistent with ISO 7919-4 which deals with shaft vibration for the same class of machines. However, ISO 7919-4 as well as this part of ISO 10816 may be revised in the future to give different criteria for gas turbine driven sets mounted on massive concrete foundations and those mounted on lighter, tuned steel foundations, if additional analysis of survey data on such machines shows it to be warranted.

The common measurement parameter for assessing machine vibration severity is velocity. Table A.1 presents the evaluation zone boundaries based on r.m.s. (root-mean-square) velocity measurements. In many cases, however, it was customary to measure vibration with instruments scaled to read peak rather than r.m.s. vibration velocity values. If the vibration consists mainly of one frequency component, a simple relationship exists between the peak and r.m.s. values and the zone boundaries of table A.1 may be readily expressed in zero-to-peak values by multiplying by $\sqrt{2}$.

For gas turbine driven sets, it is common for the vibration to be predominantly at the running frequency of the machine. For such cases and when peak rather than r.m.s. values of vibration are being measured, a table equivalent to table A.1 can be constructed. The zone boundaries of table A.1 are multiplied by a factor of $\sqrt{2}$ to produce such an equivalent table for assessing peak vibration severity. Alternatively, the measured peak vibration values may be divided by $\sqrt{2}$ and judged against the r.m.s. criteria of table A.1.

4.1.3 Axial measurements

It is not common practice to measure axial vibration on the radial load carrying bearings of gas turbines during continuous operational monitoring. Such axial measurements are primarily used for periodic vibration surveys or for diagnostic purposes. When axial vibration is measured on an axial thrust bearing, the severity may be judged using the same criteria as for radial vibration.

4.2 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference value. A significant increase or decrease in broad-band vibration magnitude may occur which requires some action even though zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and may indicate incipient damage or some other irregularity. Criterion II is specified on the basis of the change in broad-band vibration magnitude occurring under steady-state operating conditions. Such conditions allow for small changes in variables such as generator power output at the normal operating speed.

When Criterion II is applied, the vibration measurements being compared shall be taken at the same transducer location and orientation, and under approximately the same steady-state operating conditions of speed, load, and thermal condition. Significant changes from the normal vibration magnitudes should be investigated so that a dangerous situation may be avoided. When an increase or decrease in vibration magnitude exceeds 25 % of the upper value of zone B, such changes should be considered significant. Diagnostic investigations should then be initiated to ascertain the reason for the change and to determine what further actions are appropriate.

NOTE The 25 % value is provided as a guideline for a significant change in vibration magnitude, but other values may be used based on experience with a specific machine.

4.3 Operational limits

For long-term operation, it is common practice to establish operational vibration limits. These limits take the form of ALARMS and TRIPS.

ALARMS: To provide a warning that a defined value of vibration has been reached or a significant change has occurred, at which remedial action may be necessary. In general, if an ALARM situation occurs, operation can continue for a period whilst investigations are carried out to identify the reason for the change in vibration and define any remedial action.

TRIPS: To specify the magnitude of vibration beyond which further operation of the machine may cause damage. If the TRIP value is exceeded, immediate action should be taken to reduce the vibration or the machine should be shut down.

In order to perform an investigation on the unit running at steady-state conditions but gradually proceeding to the vibration TRIP value, actions may be taken, such as reduction in load and speed, to stabilize the vibration to a constant or a lower value.

4.3.1 Setting of ALARMS

The ALARM values may vary considerably, up or down, for different machines. The values chosen will normally be set relative to a baseline value determined from experience for the measurement position or direction for that particular machine.

It is recommended that the ALARM value should be set higher than the baseline by an amount equal to 25 % of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C.

Where there is no established baseline (for example with a new machine) the initial ALARM setting should be based either on experience with other similar machines or relative to agreed acceptance values. After a period of time, the steady-state baseline value will be established and the ALARM setting should be adjusted accordingly.

Where the baseline signal is non-steady and non-repetitive, some method of time averaging of the signal is required. This could be achieved with the aid of a computer.

It is recommended that the ALARM value should not normally exceed 1,25 times the upper limit of zone B.

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly. Different operational ALARM settings may then exist for different bearings on the machine, reflecting differences in dynamic loading and bearing support stiffnesses.

An example of establishing ALARM values is given in annex B.

4.3.2 Setting of TRIPS

The TRIP values will generally relate to the mechanical integrity of the machine. The values used will, therefore, generally be the same for all machines of similar design and would not normally be related to the steady-state baseline value used for setting ALARMS.

There may, however, be differences for machines of different design and it is not possible to give clear guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D, but it is recommended that the TRIP value should not exceed 1,25 times the upper limit of zone C. However, experience with a specific machine may prescribe a different value.

4.4 Supplementary procedures/criteria

The measurement and evaluation of vibration given in this part of ISO 10816 may be supplemented or replaced by shaft vibration measurements in accordance with ISO 7919-4. It is important to recognize that there is no simple way to relate bearing housing vibration to shaft vibration, or vice versa. The difference between the shaft absolute and shaft relative measurements is related to the bearing housing vibration but may not be numerically equal to it because of phase angle differences. Thus, when the criteria of this part of ISO 10816 and those of ISO 7919-4 are both applied in the assessment of machine vibration, independent shaft and bearing housing (or pedestal) vibration measurements should be made. If application of the different criteria leads to different assessments of vibration severity, the more restrictive zone classification generally applies unless there is significant experience to the contrary.

4.5 Evaluation based on vibration vector information

The evaluation considered in this part of ISO 10816 is limited to broad-band vibration without reference to frequency components or phase. This will, in most cases, be adequate for acceptance testing and for operational monitoring purposes. However, for long-term condition monitoring purposes and for diagnostics, the use of vibration vector information is particularly useful for detecting and defining changes in the dynamic state of the machine. In some cases, these changes would go undetected when using only broad-band vibration measurements (see, for example, ISO 10816-1).

Phase- and frequency-related vibration information is being used increasingly for monitoring and diagnostic purposes. The specification of criteria for this, however, is beyond the present scope of this part of ISO 10816.

Annex A (normative)

Evaluation zone boundaries

Table A.1 — Evaluation zone boundaries based on bearing housing/pedestal vibration velocity, valid for shaft rotational speed 3 000 r/min to 20 000 r/min

Zone boundary	Vibration velocity mm/s (r.m.s.)
A/B	4,5
B/C	9,3
C/D	14,7

NOTE These values, which are the upper limits of zones A, B and C respectively, should apply to radial vibration measurements on all bearing housings or pedestals and to axial vibration measurements on housings containing an axial thrust bearing, under steady-state operating conditions at rated speed. Figure 1 shows typical measurement positions.

Annex B

(informative)

Example of setting ALARM and TRIP values

Consider the case of a 3 000 r/min gas turbine. The operational ALARM settings for a new machine for which there is no prior knowledge of bearing vibration is normally set within zone C. The specific value is often set by mutual agreement between the customer and the machine manufacturer. For this example, assume it has been set initially at the lower limit of zone C for each bearing, which corresponds to 9,3 mm/s (r.m.s.).

After a period of machine operation, the customer may consider the option of changing the ALARM settings to reflect the typical steady baseline values of vibration at each bearing. Using the procedure described in 4.3.1 as the basis, the ALARM may be set for each bearing to equal the sum of the typical steady-state value obtained from experience with the specific machine, and 25 % of the upper limit of zone B.

The TRIP setting would remain at 14,7 mm/s (r.m.s.) in accordance with Criterion I. The basis for this is that the TRIP value is a fixed value corresponding to the maximum vibration to which the machine should be subjected.

Annex C (informative)

Bibliography

- [1] ISO 2954:1975, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*
- [2] ISO 7919-1:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines.*
- [3] ISO 8579-2:1993, *Acceptance code for gears — Part 2: Determination of mechanical vibrations of gear units during acceptance testing.*
- [4] ISO 10816-2:1996, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Large land-based steam turbine generator sets in excess of 50 MW.*
- [5] ISO 10816-3:—¹⁾, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.*

1) To be published.

ICS 17.160; 27.040

Descriptors: vibration, machinery, gas turbine engines, tests, mechanical tests, vibration tests, acceptance testing, estimation, vibration severity.

Price based on 9 pages
